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THE DIPTERA BREEDING ON SKUNK CABBAGE, *SYMPLOCARPUS FOETIDUS* (ARACEAE)

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Abstract.—The larvae of 19 species of flies belonging to 7 families were found to feed in the rotting portions of leaves, petioles, and flowers of skunk cabbage. Among flies bred from this plant, drosophilids were by far the most numerous, but there is considerable geographic and seasonal variation in composition and abundance of the fauna. The sex ratio of one species, a *Bryophaenocladius* sp. (Chironomidae), reveals it to be parthenogenetic. The breeding biology of the flies, with particular reference to other dipteran-aroid relationships, is reviewed.

Symplocarpus foetidus is a common perennial plant of wet lowland areas in eastern North America. Inflorescences appear in early spring, the leaves expand about one month later, and seeds are formed in the fall, when the above-ground portion of the plant dies back. This species forms established patches that may vary in size from a few square meters to several hectares. *Symplocarpus foetidus* would thus seem to be an "apparent" plant to potential consumers, and as such one might expect it to be protected by "quantitative" defenses (sensu Feeny, 1976). It is: the tissues contain barbed crystals of calcium oxalate, which may deter a variety of herbivores (B. Meeuse, pers. comm.). An herbivore that would cope with this defense, however, would be rewarded with a predictable supply of food. Hence, specialization of some herbivore species on *S. foetidus* might be expected to evolve.

Although a few Coleoptera, Psocoptera and Collembola breed in skunk cabbages, the majority of insects bred from the plant are a variety of dipterans. We have never seen visible signs of serpentine or blotch mines, chewing areas, or petiole girdling which might be indicative of insect activity. All flies in this study were bred from rotting portions of plants and most likely fed on bacteria harbored therein. This does not, however, rule out the possibility that diptera may be the cause of decay in the portions of some plants. We show here that *Symplocarpus foetidus* is probably the major breeding site of the Holarctic species *Scaptomyza graminum.* Another significant finding is that *Drosophila recens,* previously thought to breed exclusively in mushrooms, also utilizes *Symplocarpus* as well.

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METHODS

One collection of 22 flowers (including the spathe and spadix) was made from two *Symplocarpus* patches on Deer Isle, Maine on June 28, 1982. Three collections of 37, 27, and 28 plants were made on May 14, June 25, and August 6, 1982, respectively, at Chenango Valley State Park, Chenango, New York. Only flowers were collected in May, since rotting or damaged leaves were not found. Rotting and damaged petioles and leaves, all from different plants, comprised the specimens thereafter, as spathes were uncommon. Portions of plants were bagged and transported to the laboratory, where they were placed on damp sand (except for the Maine collections, which were placed on Instant *Drosophila* medium [Carolina Biol. Suppl. Co.]) in 200 ml plastic containers covered with cardboard tops. To prevent drying, the specimens were misted every other day with water. Adult insects were aspirated as they emerged and were preserved in 70 percent ethanol prior to identification.

Insects were identified using the following references: Wheeler (1960) and Strickberger (1962) for *Drosophila,* Wheeler (1952) for Drosophilidae other than *Drosophila,* Johannsen (1952) for Chironomidae and Ceratopogonidae, Saether (1973) for *Bryophaenocladius* sp., and Quate (1960) for Psychodidae. *Scaptomyza* 'sp. *A*' appears to be a new species and will probably be described later. Voucher specimens are deposited in the Cornell University collection, Ithaca, New York. Our identification of *Dasyhelea* was confirmed by Dr. Willis W. Wirth and the ephydrid and chloropids were identified by Drs. W. N. Mathis and C. W. Sabrosky, respectively, all of the Systematic Entomology Laboratory of the U.S. Department of Agriculture.

RESULTS AND DISCUSSION

The most conspicuous aspect of the breeding records (Tables 1 and 2) is the complete absence of parasitic Hymenoptera: from a total of 1,132 potential dipteran hosts reared (an average of 10 flies per plant part), not one parasite emerged. This contrasts with the number of parasitic braconids and cynipids bred from mushrooms containing Diptera also growing at the Chenango Valley site (Grimaldi, 1983). Carson et al. (1980) also bred numerous small wasps from another primary dipteran breeding site, the aroid *Calocasia esculenta* in Papua New Guinea.

Not so surprising is the seasonal variation in abundance of some flies, since insect populations generally fluctuate in abundance seasonally. For instance, none of the nematocera present during the spring and early summer breed in *Symplocarpus* in late summer in New York. In contrast, *Scaptomyza graminum* abundance increases almost four-fold towards late summer. *Drosophila recens,* which is the most common fly in the spring collection, is virtually nonexistent in the later collections. Of particular interest is the

Table 1. Drosophilidae reared from *Symplocarpus foetidus* (N = 672).

Species	Numbers		
	Males	Females	Total
Chenango Valley, New York, May 1982: flowers, 37 plants			
Drosophila recens Wheeler	62	84	146
Scaptomyza graminum Fallén	11	15	26
Drosophila affinis-subgroup	5	15	20
Scaptomyza sp. *A*	8	4	12
Drosophila putrida Sturtevant	6	4	10
Drosophila falleni Wheeler	7	2	9
Drosophila palustris Spencer	1	4	5
Chymomyza amoena Loew	2	3	5
			233
Chenango Valley, New York, June 1982: leaves and petioles, 27 plants			
Scaptomyza graminum	42	36	78
Drosophila palustris	1	6	7
Scaptomyza sp. *A*	2	1	3
			88
Deer Isle, Maine, June 1982: flowers, 22 plants			
Drosophila quinaria Loew	17	20	37
Drosophila busckii Coquillett	2	3	5
Drosophila recens	1	1	2
			44
Chenango Valley, New York, August 1982: leaves and petioles, 28 plants			
Scaptomyza graminum	137	144	281
Scaptomyza sp. *A*	7	12	19
Scaptomyza paravittata Wheeler	3	4	7
			307

geographic variation of species breeding in skunk cabbages. *Drosophila quinaria,* which is common in *S. foetidus* in Rochester, New York and Deer Isle, Maine (Jaenike, 1978) is not present in the Chenango Valley population. In the latter area, *D. recens* is the predominant species of *Drosophila* bred from this plant.

The Araceae appears to be a pivotal resource in the ecological diversity of the Drosophilidae. The niche is typical of *Scaptomyza,* which are leaf miners. We have bred a large number of *S. graminum* (=*S. borealis* [Wheeler, 1981]) from skunk cabbages (this study and Jaenike, 1978). This drosophilid has, however, been found, occasionally, to use some non-araceous resources, such as *Stellaria aquatica* (Caryophyllaceae) in Japan (T. Okada, pers. comm.), *Nasturtium officinalis* (Cruciferae) (Wheeler, 1952), *Petasites officinalis* (Compositae), *Brassica campestris, B. oleracea, B. rapa* (Cruciferae), and

Table 2. Non-drosophilid Diptera reared from *Symplocarpus foetidus* (N = 460).

Family	Species	Numbers		
		Males	Females	Total
Chenango Valley, New York May 1982: flowers, 37 plants				
Psychodidae	*Psychoda satchelli* Quate	29	52	81
	Psychoda alternata Say	2	4	6
Chloropidae	*Tricimba lineella* (Fallén)			94
	Elachiptera costata (Loew)			11
				192
Chenango Valley, New York, June 1982: leaves and petioles, 27 plants				
Psychodidae	*Psychoda satchelli*	33	35	68
Ceratopogonidae	*Dasyhelea oppressa* Thomsen	31	36	67
Chironomidae	*Bryophaenocladius* sp.	0	29	29
Chloropidae	*Tricimba lineella*			2
				166
Deer Isle, Maine, June 1982: flowers, 22 plants				
Psychodidae	*Psychoda satchelli*	12	11	23
Ceratopogonidae	*Dasyhelea opressa*	9	3	12
Chloropidae	*Elachiptera costata*			18
Ephydridae	*Athyroglossa granulosa* (Cresson)			5
				58
Chenango Valley, New York, August 1982: leaves and petioles, 28 plants				
Cecidomyiidae	*Dyodiplosis* sp.	19	22	41
Ephydridae	*Athyroglossa granulosa*			3
				44

Aquilegia vulgaris (Ranunculaceae) (Frost, 1923). Stalker (1945) has bred *S. graminum* from *Trifolium pratense* leaves, but mentions this is not a major resource since so few individuals were reared. Stalker also found that *S. graminum* in Rochester, New York, like the flies bred in this study, are most abundant throughout the summer and early fall as found by sweep netting in open areas. In addition, R. Lacy (pers. comm.) has bred 13 individuals of *S. graminum* from a very extensive collection of mushrooms. Our data show that a major larval resource of *Scaptomyza graminum,* perhaps the most abundant species of its genus, is *Symplocarpus foetidus.*

In the *Drosophila quinaria* species group, some members, such as *D. quinaria* and *D. magnaquinaria,* specialize on aroids (Jaenike, 1978; Wheeler, 1954; this study). Other species in the group (such as *D. falleni, D. phalerata,* and *D. transversa*) breed in a diversity of mushrooms (Jaenike, 1978; Lacy, 1982; Grimaldi, 1983; Shorrocks, 1980). *Drosophila recens* and *D. limbata* are intermediate, breeding in both mushrooms and aroids. *D. limbata* has been bred from *Arum maculatum* fruits (Schatzmann, 1977)

and from *Russula* mushrooms (Burla and Bächli, 1968) in Switzerland. *D. recens* commonly breeds in mushrooms, but utilizes *Symplocarpus* in the spring before mushrooms are fruiting.

Although the bulk of dipteran-aroid relationships in the tropics has yet to be investigated, Heed (1957) gives an indication of the potential importance of this relationship in structuring Neotropical drosophilid communities. Approximately one-quarter of the 222 species of Drosophilidae collected in El Salvador can be found in "aroid swamps," of which *Xanthosoma* is a characteristic plant. In Papua New Guinea, Okada and Carson (1979) and Carson and Okada (1980) have found that several aroids are a "veritable zoological garden" for drosophilids. Four drosophilid species were reared from *Colocasia esculenta,* and 13 different species reared from *Alocasia macrorrhiza.* The larvae of most of these species feed on spathes and spadices, and are quite monophagous. *Drosophila aproclinata,* for example, breeds only in decaying staminate portions of *Alocasia hollrungii* spadices. Like most of the *Drosophila* breeding in *Symplocarpus,* Carson and Okada found the New Guinea *Drosophila* limited to breeding in the flowers. It appears that throughout the world the Araceae have repeatedly been invaded by Drosophilidae.

For some drosophilids, *Symplocarpus foetidus* is just an incidental resource. For example, only 20 individuals of the extremely abundant *Drosophila affinis* subgroup were bred in this study. *Drosophila putrida, D. falleni, D. busckii,* and *Chymomyza amoena* are also, judging from their numbers bred from other substrates and caught in banana traps, just incidental rearings.

Another interesting parallel between New Guinea aroid-breeding flies and the kind we have bred are the Psychodidae. For a family with larvae generally breeding in detritus (Quate, 1960) such as compost and decaying organic matter (Johannsen, 1934), aroids are an unusual niche. But, about one-third of the non-drosophilid Diptera in *Symplocarpus foetidus* are *Psychoda.* Carson and Okada (1980) also found several psychodids breeding in *Calocasia esculenta.* Quite unusual for cecidomyiids are our records for *Dyodiplosis* sp. in *Symplocarpus.* Decaying vegetation may not be an unusual niche for *Dyodiplosis* since it occasionally is found in some of our mushroom rearings.

Symplocarpus is not an unusual niche for the other nematocera and the ephydrid and chloropids bred in this study. Ephydridae and Chloropidae are commonly associated with wet areas, many members of both these families boring the stems of plants. Although ceratopogonids and chironomids are almost entirely aquatic groups, *Dasyhelea* and *Bryophaenocladius,* which were bred from skunk cabbages, are among the more derived, terrestrial forms. *Dasyhelea oppressa* is common in bleeding exudates of Elm (*Ulmus*) trees in New York (Thomsen, 1937). At least three *Dasyhelea* species breed in cacti (Wirth and Hubert, 1960). Other ceratopogonids are quite

terrestrial, larvae of *Forcipomyia argenteola* group species commonly breeding in decaying portions of banana stems, cacao pods, and *Calathea* and *Heliconia* bracts in the Neotropics (Wirth, 1982). *Bryophaenocladius,* together with *Smittia* and *Pseudosmittia,* belongs to a related group of Orthocladiinae, some members of which Johannsen (1937) records as breeding in and among plant roots. Parthenogenesis occurs repeatedly in the Chironomidae, but is most frequent primarily in only the Orthocladiinae among the eight subfamilies usually recognized. In the Orthocladiinae, species belonging to 8 genera, including *Bryophaenocladius,* are known to be obligately or facultatively thelytokous (Scholl, 1960). Oliver et al. (1972) used emergence trap data to show female-biased sex ratios occur in three additional genera of this subfamily.

Most Diptera raised in this study, with the exception of some drosophilids (and possibly chloropids), probably breed in plant matter other than decaying *Symplocarpus.* Nematocera breed in detritus, on the whole, with several of the species mentioned here adding the bacterial flora of decayed skunk cabbage to their diet.

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